

Research Ships of Opportunity Program

PROJECT NEPTUNE LIMNOS

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## ABSTRACT

Two previous projects have proven that oceanographic data collection and biological experimentation can be carried out aboard a merchantman (Research Ship of Opportunity concept). This third project was designed to determine if questions of scientific importance could be answered from research carried out in this way. The scientific objective of the third study was to compare the biological communities sampled during passage from Detroit, Michigan, out the St. Lawrence and across the open Atlantic to Bilbao, Spain. The experience on this project points up the desirability, in any large-scale use of this concept, of a central agency to coordinate preparations. Samples have been gathered for measurement of the amount of particulate organic matter, the amount of dissolved organic matter, and the composition of the plankton community. The analysis of these samples is not yet complete, but the preliminary indications are that the objective of showing that a RSO project can obtain results with intrinsic scientific value will be fulfilled.

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## INTRODUCTION

### Background

The amount of oceanographic research in the United States has been increasing very rapidly in recent years, placing a severe strain on the existing facilities available for such work. Unfortunately, although the potential rewards of an increased knowledge of the oceans are great, so also are the costs involved in obtaining this knowledge.

It has been suggested that merchant ships might be utilized to economically increase our capacity to gather oceanographic data. This idea, referred to as the Research Ships of Opportunity (RSO) concept, is not new and already has proven successful for gathering certain types of data. For example, an extensive survey of the North Atlantic and North Sea plankton has been carried out over the past thirty years in Britain, using samples collected by merchant ships and Ocean Weather Ships towing the Continuous Plankton Recorder (Glover, 1962).

In the fall of 1964, a preliminary feasibility study, called Project Neptune, was undertaken to test the use of American merchantmen to gather oceanographic data on their regularly scheduled voyages. The test was conducted aboard the S.S. JAVA MAIL of the American Mail Line, from Seattle, Washington, to Hong Kong. It was conducted jointly by the Defense Research Laboratories of General Motors, Santa Barbara, California, and the Life Sciences Department of the U. S. Naval Missile Center, Point Mugu, California, under a contract from the Marine Biology Branch of the Office of Naval Research. The study revealed that the RSO concept is feasible with regard both to the collection of data and to the cost of the operation. The project has been reported by the U. S. Naval Missile Center (Maag, Evans, and Broman, no date) and by the GM Defense Research Laboratories (Aron, 1965).

The second phase of the test of the RSO concept, also supported by an ONR contract, was undertaken in the summer of 1965 by scientists from Florida Atlantic University. It was called Project Neptune Atlantic and was conducted on board the S.S. EXPORT CHAMPION of the American Export Isbrandtsen Lines from New York to Genoa, Italy. Its objective was to determine the feasibility of conducting physiological experiments on plankton samples gathered from a high-speed merchantman. It was concluded that the RSO concept is applicable to biological experimentation at sea.

However, several problems in collecting and studying the organisms were encountered which would have to be overcome before fully successful physiological experimentation could be carried out (Stephan and Hoffmann, no date).

#### Purpose of Project Neptune Limnos

The first two phases of the test of the RSO concept showed that data collection and biological experimentation could be carried out from a mobile laboratory put aboard a merchant ship without unduly interfering with the ship's primary function. However, these studies were not designed to produce substantial scientific results apart from demonstrating the feasibility of the RSO concept. The overall purpose of the present work, referred to as Project Neptune Limnos, was to show that results with intrinsic scientific value could be obtained under the conditions imposed by the use of a merchantman and a mobile laboratory. A further objective was to show that aquatic scientists from inland areas can make a valuable contribution to the national effort in oceanography. The research was supported by a contract from ONR to the Great Lakes Research Division of the University of Michigan with Dr. David C. Chandler serving as Project Director.

#### Scientific Objective

The waters of a river system undergo gradual changes as they flow toward the sea. Yet, for practical reasons, no comparative studies have been made of a large river system, its estuary, and the open ocean during the same investigation and with the same methods and procedures. The scientific objective of this study was to accomplish this by comparing certain properties in the waters of the St. Lawrence River system, starting approximately 800 miles from the sea at Detroit and extending out into the open Atlantic. The properties selected to be studied were the amount of particulate organic matter, the amount of dissolved organic matter, the composition of the plankton community, the temperature, and the conductivity. These were selected because it was felt that they would allow meaningful comparisons to be drawn between the biological communities in the different environments and because the author was personally familiar with the measurement of these properties.

### Purpose of this Report

This report is intended to describe the experiences in planning, preparing for, and carrying out Project Neptune Limnos as well as the conclusions and suggestions arising from the project. The scientific results will not be fully reported now, but will appear in future scientific publications when the samples collected during the field part of the work have been completely processed and the data analyzed. It is hoped the experiences related here and the conclusions reached will aid in the planning and execution of future research utilizing Research Ships of Opportunity. Also, together with the reports from the original Project Neptune and Project Neptune Atlantic, this report is intended to act as an aid in determining what part the RSO concept should play in our national oceanographic program.

## PLANNING

### Contact with Previous Projects

Besides studying the reports from the two previous RSO projects, the author visited Professors Stephan and Hoffmann of Florida Atlantic University, to learn about their experiences on Project Neptune Atlantic. The author also attended a debriefing session for the Atlantic project in Washington in October 1965, where he met with members of both previous expeditions. As many of the problems encountered on the different cruises were similar, these contacts were an invaluable aid in carrying out Project Neptune Limnos. It is suggested that such contacts should be included in the planning of any future RSO program. Possibly a written outline of past experience including the problems likely to be encountered and how to overcome or avoid them would be useful.

### Negotiations with the Shipping Company

Obviously the approval of the company whose ship was to be used had to be obtained before any further arrangements could be made. Our original contact was with the Moore-McCormack Lines for use of a ship from Toledo, Ohio, to Rio de Janeiro, Brazil. They gave us tentative approval, and then found they would be unable to work with us because the situation in Vietnam made it uncertain whether their ships would come into the Great Lakes during 1966.

We then contacted the American Export Isbrandtsen Lines with regard to the use of one of their ships from a Great Lakes port to a European port. They gave us tentative approval to use one of their ships from Toledo, Ohio, to Spain. We proceeded with our planning on this basis. Approximately one month before our scheduled departure, the embarkation point had to be changed to Detroit, Michigan, because the ship was not going to stop in Toledo. This caused some confusion because arrangements had been made for loading in Toledo and for sending the mobile laboratory there.

A great deal of confusion could have been avoided if we had been notified as soon as the company knew they were not going to stop in Toledo, which seems to have been three or four weeks before we found out. The major difficulty here seemed to be that we were in contact with one depart-

ment while the scheduling was done by another department. It is suggested that difficulty might be avoided for any large-scale RSO program in the future if one person or agency routinely supervised negotiations between the scientists and the shipping companies. One central contact would then be familiar with the people to contact in each company and the procedures to follow to ensure smooth relations.

#### Procuring the Mobile Laboratory

In order to minimize interference with the normal operation of the ship, it was decided to place a mobile laboratory aboard as had been done on the two previous expeditions. We requested the use of a mobile laboratory, like the one described by Westwick and Maag (1965), from the U. S. Naval Missile Center, Point Mugu, California, where they had been obtained previously. We were informed in November 1965 that we should make this request as soon as possible. However, we had just submitted our proposal for the project at that time, and so we delayed until January 1966 when we had a more definite idea as to whether we would be needing the laboratory. By the time our request was received, all the mobile laboratories had been committed for the summer of 1966. Fortunately, the lab employed on Project Neptune Atlantic was still being used by Florida Atlantic University and the use of this for our work was made possible through the courtesy of Professor Stephan (Fig. 1).

For many survey oriented programs using the RSO concept, a mobile laboratory might not be required. However, for projects where any considerable amount of space for onboard research is needed, they are almost mandatory since the space that can be made available on a merchantman is, in most cases, limited and unsuitable for scientific research. Thus, any large-scale national use of this concept for other than survey work should make provision for providing a pool of mobile labs that could be made available on fairly short notice.

#### Contact with the Port of Embarkation

Being generally unfamiliar with the problems involved in loading and unloading material from a commercial vessel, we originally contacted the Port Authority at Toledo, our scheduled point of departure. Our contacts there were very helpful and promised their assistance and advice in any



Figure 1. Sea-van on dock at Detroit before loading.



Figure 2. EXILONA at dock in Detroit before cruise.

way possible with our project. They assured us that the mobile lab could be sent directly to their port facilities where we could equip and, when we returned, dismantle the lab facilities. This was especially helpful because we had no convenient place to fit out at the University of Michigan, and because this eliminated the need for reshipment from Ann Arbor to the embarkation port after fitting out.

Of course, when the departure point was changed, we could no longer rely on this assistance and had to make new contacts in Detroit. Fortunately, everything went quite smoothly, but without the expert advice we received in Toledo there were times when a course of action had to be taken without assurance that it was the proper procedure. For future RSO work it would be useful, as for the contacts with the shipping companies, if a centralized agency could coordinate this part of the work rather than leaving it entirely up to the inexperienced scientist.

#### Preliminary Visit to the Ship

American Export Isbrandtsen Lines suggested that their ship S.S. EXILONA would be the only one suitable for our work with regard to accommodations for the scientific party. We visited the ship in Detroit on 16 May 1966 during her first voyage of the year into the Great Lakes (Fig. 2), to familiarize ourselves with the general layout of a merchantman and to discuss our plans with the captain as well as to get his opinion as to any problems that might arise. The visit was very valuable; however, its usefulness could have been increased if the ship's officers could have been informed beforehand as to the purpose of our visit and the work we hoped to carry out. It was very difficult for the scientists to explain what was needed with regard to such technical problems as providing electricity for the lab and installing a temperature probe in the water intake because of lack of knowledge and experience of such matters. Here again a central agency with RSO experience would greatly facilitate operations by acting as a coordinator between the ship and the scientists.

## PREPARATIONS

### Procurement of Equipment

While we had on hand much of the basic scientific equipment for our work, we found it necessary to procure several large pieces of equipment. These included a freezer, an air-conditioner, a winch, and electrical equipment to provide the lab with power. The freezer and air-conditioner were not difficult to buy as they were readily available at retail outlets in Ann Arbor. The other two pieces of equipment were more difficult. It was felt necessary to inspect the ship and get the advice of the officers before these were ordered. Then, as we were about to order, the shipping company notified us that they would not be stopping in Toledo and uncertainty arose as to whether we would be able to use the EXILONA at all during the summer of 1966. Our ordering had to be postponed until we had a better idea of our final arrangements and needs, cutting our margin for delivery of the winch and electrical equipment very close. Fortunately, with the aid of many long-distance phone calls we were able to obtain the equipment on time.

Another difficulty arose in deciding what type of electrical equipment was needed. The scientists involved with the project had very little knowledge of electrical engineering. The matter was discussed with the chief engineer on board the EXILONA, but he could only help in a general way because he had not seen the lab and seemed uncertain about what types of equipment could be obtained. Although we obtained the advice of everyone we could find who seemed to have some knowledge along these lines, we had to order with no real assurance we were obtaining the proper equipment. As will be discussed in a later section, we were able to accomplish our work with the equipment obtained, but we did not get that best-suited for our job.

Here again a coordinating agency could have greatly facilitated the work. There are several general types of electrical set-ups in use on American merchant vessels. The central agency could have a supply of the equipment, i.e., converters, generators, etc., needed for each situation and could furnish advice as to what would be needed to accomplish the projected research.

#### Shipment of the Mobile Laboratory

The mobile lab arrived from Florida Atlantic University about ten days before our scheduled departure. It was delivered to the Detroit Marine Terminal where we secured permission to enter to make alterations and to load our equipment. The lab was shipped over the road by flatbed truck and arrived in good condition.

#### Contact with the Detroit Agent

The Steamship Agencies acted as agent for the American Export Isbrandtsen Lines in Detroit. They kept us informed as to the tentative sailing date, told us where to ship the lab, and made arrangements so that we could work on the lab after its arrival at the terminal.

#### Procurement of Tickets

The scientific party traveled as passengers so it was necessary to obtain tickets. This was done through a travel agency in Ann Arbor with no trouble.

#### Procurement of Passports and Health Certificates

Passports and health certifications were obtained in the usual way.

#### Second Visit to the Ship

The EXILONA was visited for a second time on her stop in Detroit during her second inbound journey of the year into the Great Lakes. During this visit we told the captain and chief engineer our final plans and made arrangements to come aboard when the ship returned to Detroit on her outbound voyage.

## THE CRUISE

### The Scientific Party

The scientific party consisted of Dr. Andrew Robertson, Chief Scientist (Assistant Research Limnologist, Great Lakes Research Division, University of Michigan), and Mr. Grant M. Barkley, Scientific Assistant (a student from Western Michigan). This was a smaller party than carried on the previous RSO cruises but seemed adequate for the work planned. Although the routine varied somewhat depending on the speed with which we expected the environment to be changing, we usually took samples every four hours. One of us would be on duty for two sampling times and then the other person would take over for the next two collections. Each sampling took from one to one and one-half hours, so that at least fourteen hours a day were left free. The only exceptions were for jobs that required two people, such as launching and retrieving the Continuous Plankton Recorder.

### Loading and Unloading the Laboratory

The loading and unloading of the lab was handled as with any other piece of cargo (Fig. 3). No problems were encountered.

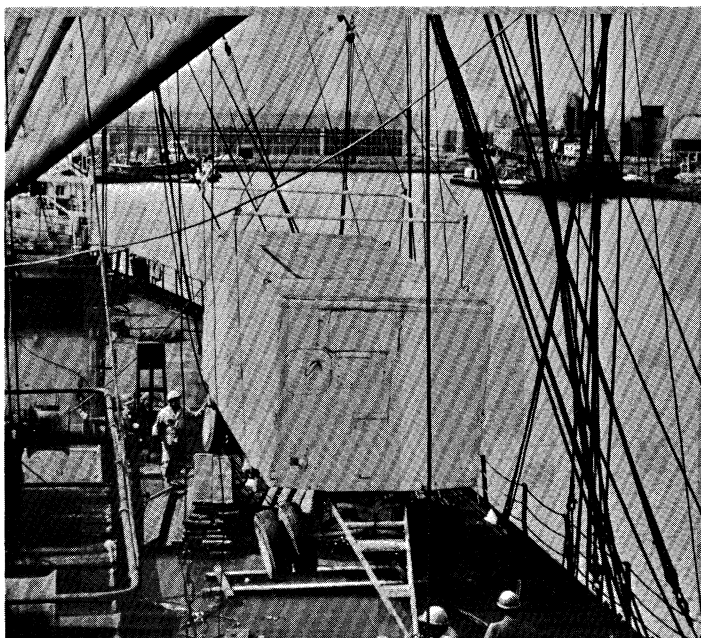


Figure 3. Unloading sea-van at Detroit.

### Securing the Laboratory

The lab was lashed down under the rigging and then secured with lumber blocking the tires (Figs. 4-5). The only problem was that the lab had to be moved several times during the voyage to permit the loading and unloading of other cargo, necessitating moving and resecuring the lab, which was inconvenient. The moving also made it necessary to leave on the tires during the voyage, which was no hardship in our case but might have been if we had attempted any delicate work such as use of a microscope.

Stephan and Hoffmann (undated) state that tires can accentuate the ship's vibrations.

### Cruise Path

The EXILONA left Detroit on 25 July 1966 and arrived in Bilbao, Spain, on 6 August 1966 with one stop of approximately 20 hours in Montreal, Canada. The ship's course is shown in Figure 6.

### Providing the Laboratory with Electrical Power

The ship used 220 volts DC power, while 120 volts AC were needed to run our equipment. We obtained two motor generator sets to convert the ship's power to 120 AC. We also obtained switches and circuit breakers for each motor generator. Two small motor generators were obtained rather than one large one to facilitate handling and because the smaller sets could be obtained second-hand at a much reduced price. We wired one of the sets to supply power to the general lab equipment and lights and the other to supply the air-conditioner. This did not seem to be enough power to run the cooling unit of the air-conditioner although the fan would work. The generator used for the general lab equipment would not start after our stop in Montreal, so the other one had to be used in its place. Fortunately, we never encountered hot weather, so the use of the air-conditioner was not mandatory as it would have been had we gone to Brazil as originally planned. The engineers decided the switches and circuit breakers were not needed, so we would not have had to obtain these.

As can be seen from the above, we obtained unnecessary and under-powered equipment. Luckily this did not impair the scientific work. However, as suggested previously, a central agency with experience in RSO

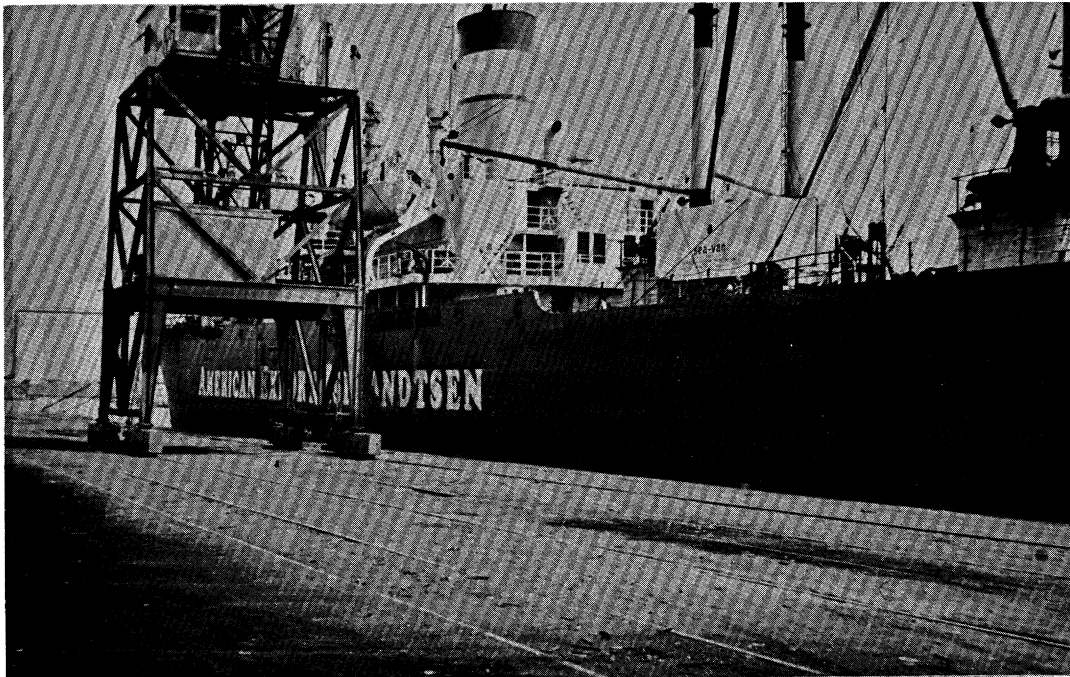


Figure 4. Sea-van in place on deck of EXILONA before departure.

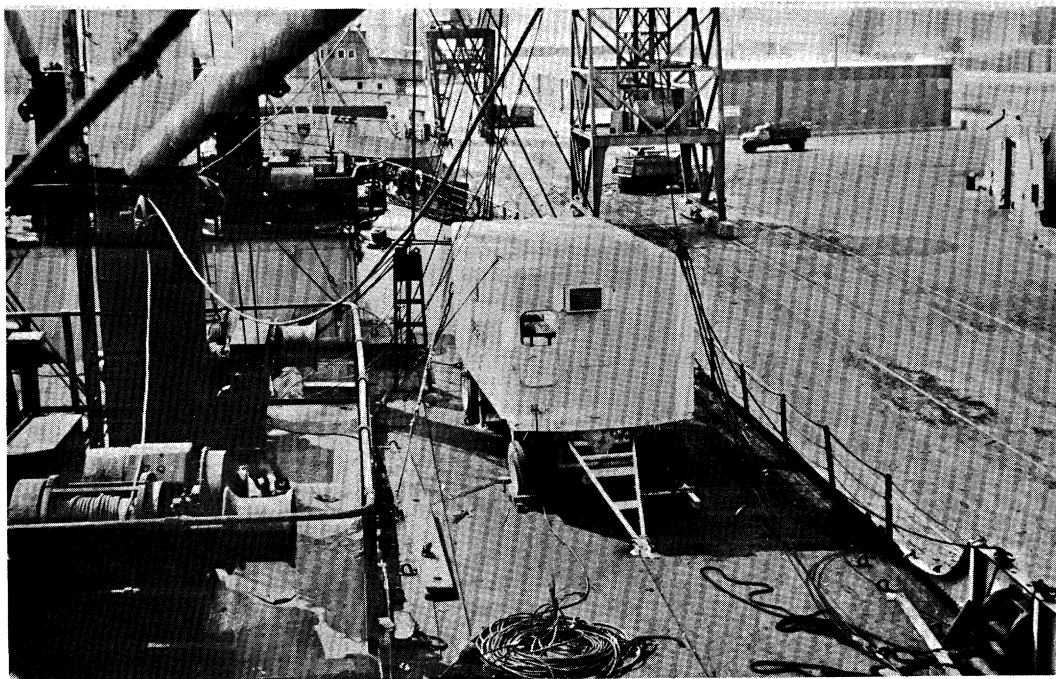


Figure 5. Sea-van under rigging with wheels blocked.

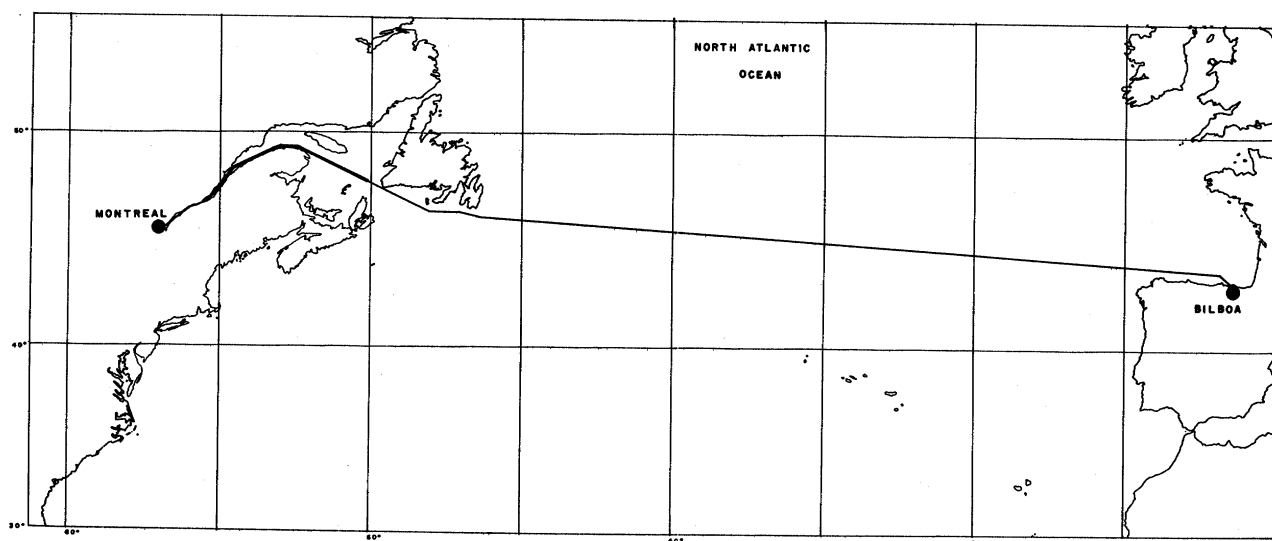
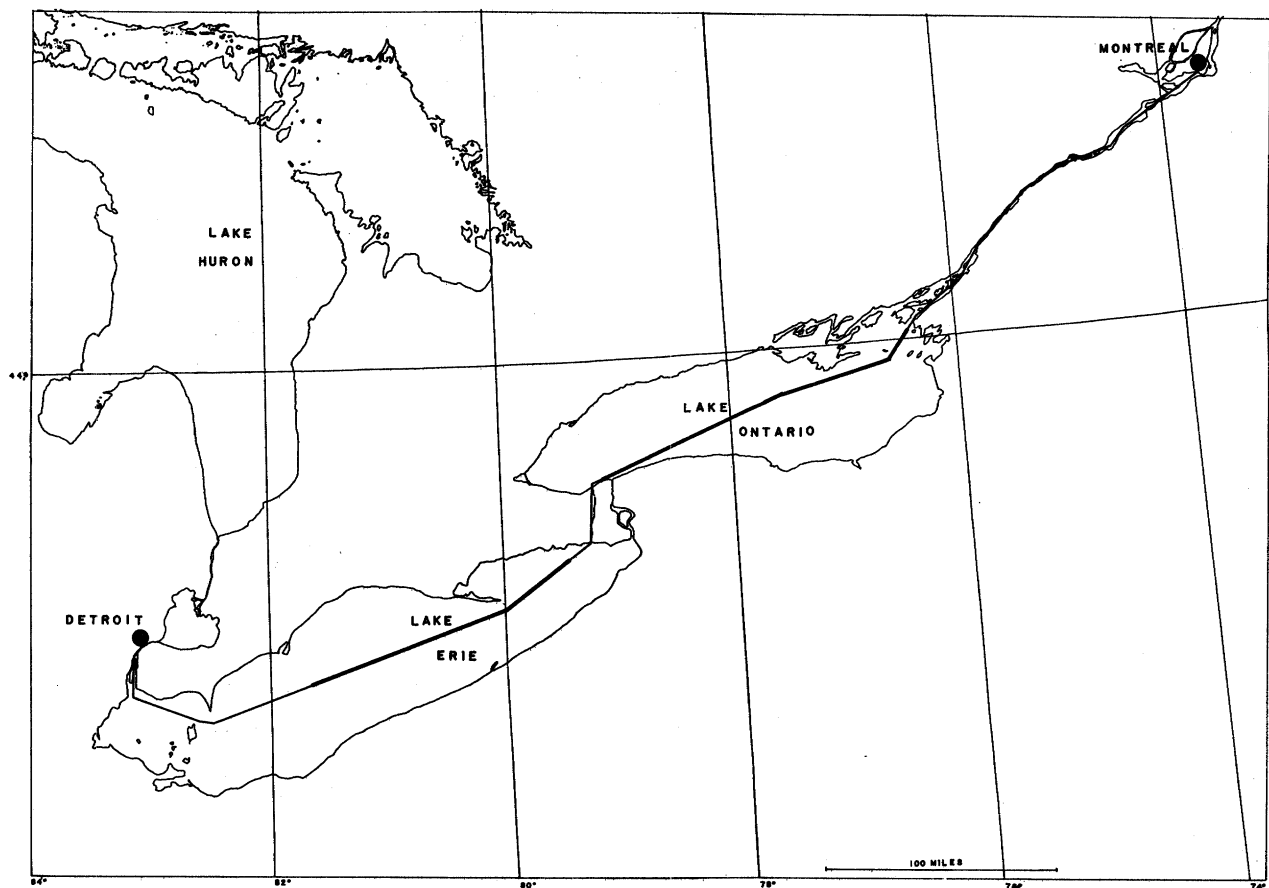


Figure 6. Cruise path. Upper chart shows path from Toledo to Montreal; lower chart path from Montreal to Bilbao. The heavier lines show where Continuous Plankton Recorder samples were obtained.

projects could have supplied us with the advice that would have enabled us to obtain the proper equipment.

### The Use of the Laboratory

The lab came to us equipped with three lockers with removable trays on one side and a work table on the other, providing us with as much storage and work space as we needed. Generally, we found the lab suitable and convenient and still with a great deal of flexibility to meet special needs.

### Accommodations

There were no other passengers and four empty passenger cabins aboard the EXILONA, so each scientist had a separate cabin. These accommodations were very good. It should be pointed out, however, that most of the merchantmen entering the Great Lakes do not have facilities for passengers and so obtaining satisfactory accommodations would be a serious problem in many instances. For example, the American Export Lines said that the EXILONA was the only one of their six ships in the Great Lakes in 1966 which had accommodations suitable for our party.

### Relations with the Officers and Crew

The ship's personnel helped us by securing the lab, moving and re-securing it when necessary, securing the winch to the deck, and connecting the lab through the motor generators to the ship's power supply. The part of this that was beyond their regular duties was considered overtime work, and they were paid accordingly. Their cooperation was excellent, and the work they did was all very good. The only real problem was that they could not secure the winch and connect up the electricity as soon as we got underway, due to their regular duties. Thus, we had to wait some time before we could tow the Continuous Plankton Recorder and use the lab for processing our samples. These problems could have been avoided if it had been possible to have a shakedown period for preparation and testing before reaching the areas of scientific interest. The usefulness of a shakedown period was demonstrated on the Pacific Project Neptune.

The personal relationships between the scientific party and the ship's officers and crew presented no problems. As was done on the previous

Neptune projects, everyone was invited to visit the lab and our work was explained to anyone who expressed interest. Both the officers and crew repeatedly offered to help us and the cooperation aboard the ship was outstanding.

#### Customs

No difficulties with customs were encountered during either loading or unloading. We provided them with a list of the equipment we were taking and filled out a Customs Form 4455 so that the material could enter the country again. The list was then checked when we unloaded the lab.

## THE SCIENTIFIC WORK

### Obtaining Water Samples

The water samples needed for our work were obtained from the main injection line of the vessel. The main injection line penetrates the hull at a depth of approximately 24 feet, is 3 feet in diameter, and passes about 10,000 gallons of water per minute. The samples were drawn from the line in the engine room through a piece of copper tubing. Several liters of water were allowed to run through the tubing each time before a sample was taken. A sample was obtained every two, three or four hours while underway, depending upon the rate at which the environment was changing. The approximate positions of sampling as well as the values obtained for temperature and conductivity are presented in Table 1.

### Measurement of Temperature

It had been planned to install a thermistor in the injection line to measure temperature. However, when we boarded the ship we found the engineers wanted to mount the thermistor at the end of a vent at the top of the injection line. Mounting the thermistor in this position excluded it from the direct flow in the line and was deemed inadvisable.

The temperature was measured during the first part of the trip with a thermistor hooked up to a Wheatstone bridge and a pre-calibrated dial. As it had been planned that the apparatus would stay attached to the injection line, it was not sturdy enough for the constant moving necessary when the attachment plan was abandoned, and it became untrustworthy during the latter part of our work. After this happened, we took the rest of our temperature readings with a 0°C to 110°C mercury thermometer. The readings were obtained by immersing the thermistor or the mercury bulb in a freshly drawn water sample. The temperature was measured each time a water sample was obtained.

### Measurement of Salinity

Measurements of specific conductance compensated to a temperature of 25°C were made with a Leeds & Northrup conductivity bridge at each sampling time (Fig. 7). These measurements for salt water can be converted to salinity with the aid of the conversion table in LaFond (1951, Table XV);

Table 1. Position, temperature, and specific conductance where water samples were obtained.

Sampling No.	Date	Time (EST)	Position	Temperature °C	Specific Conductance (mhos)
1	25-VII-66	1815	83°08'W; 42°04'N	24.5	$2.73 \times 10^{-4}$
2	"	2010	82°50'W; 41°54'N	25.8	$2.75 \times 10^{-4}$
3	"	2310	81°57'W; 41°58'N	23.4	$3.31 \times 10^{-4}$
4	26-VII-66	0200	81°04'W; 42°12'N	23.8	$3.30 \times 10^{-4}$
5	"	0505	80°06'W; 42°27'N	21.6	$3.33 \times 10^{-4}$
6	27-VII-66	0820	79°09'W; 43°15'N	22.5	$3.45 \times 10^{-4}$
7	"	1020	78°25'W; 43°27'N	21.0	$3.36 \times 10^{-4}$
8	"	1155	77°51'W; 43°38'N	18.0	$3.35 \times 10^{-4}$
9	"	1400	77°05'W; 43°48'N	21.5	$3.32 \times 10^{-4}$
10	"	1610	76°21'W; 44°06'N	24.0	$3.35 \times 10^{-4}$
11	27-VII-66	1835	75°54'W; 44°22'N	21.1	$3.37 \times 10^{-4}$
12	"	2130	75°19'W; 44°49'N	21.4	$3.39 \times 10^{-4}$
13	28-VII-66	0250	74°50'W; 44°59'N	22.5	$3.40 \times 10^{-4}$
14	"	0610	74°27'W; 45°05'N	21.8	$3.35 \times 10^{-4}$
15	"	0935	73°57'W; 45°20'N	21.5	$3.41 \times 10^{-4}$
16	28-VII-66	1455	73°48'W; 45°22'N	22.3	$3.34 \times 10^{-4}$
17	29-VII-66	1655	73°30'W; 45°38'N	21.9	$3.30 \times 10^{-4}$
18	"	2100	72°32'W; 46°20'N	22.2	$3.19 \times 10^{-4}$
19	30-VII-66	0100	71°22'W; 46°46'N	21.6	$2.84 \times 10^{-4}$
20	"	0305	70°46'W; 47°01'N	21.0	$2.84 \times 10^{-4}$
21	30-VII-66	0500	70°18'W; 47°25'N	10.9	$3.46 \times 10^{-2}$
22	"	0715	69°47'W; 47°55'N	9.8	$4.05 \times 10^{-2}$
23	"	0900	69°12'W; 48°25'N	9.5	$4.90 \times 10^{-2}$
24	"	1110	68°23'W; 48°40'N	8.7	$4.74 \times 10^{-2}$
25	"	1500	66°51'W; 49°10'N	14.2	$4.65 \times 10^{-2}$
26	30-VII-66	1900	65°18'W; 49°22'N	12.1	$4.68 \times 10^{-2}$
27	"	2255	63°41'W; 48°58'N	12.6	$5.03 \times 10^{-2}$
28	31-VII-66	0255	62°19'W; 48°30'N	13.9	$5.00 \times 10^{-2}$
29	"	0705	60°48'W; 48°02'N	14.7	$4.88 \times 10^{-2}$
30	"	1115	59°20'W; 47°33'N	14.7	$5.13 \times 10^{-2}$
31	31-VII-66	1500	57°50'W; 47°06'N	13.6	$5.24 \times 10^{-2}$
32	"	1900	56°36'W; 46°40'N	14.9	$5.19 \times 10^{-2}$
33	"	2255	54°58'W; 46°33'N	16.0	$5.15 \times 10^{-2}$
34	1-VIII-66	0155	53°40'W; 46°28'N	13.1	$5.25 \times 10^{-2}$
35	"	0555	52°07'W; 46°16'N	16.5	$5.26 \times 10^{-2}$
36	1-VIII-66	1000	50°23'W; 46°11'N	14.0	$5.26 \times 10^{-2}$
37	"	1400	48°41'W; 46°07'N	15.6	$5.30 \times 10^{-2}$
38	"	1800	47°07'W; 46°02'N	17.5	$5.33 \times 10^{-2}$
39	"	2100	45°50'W; 45°58'N	18.5	$5.40 \times 10^{-2}$
40	"	0100	44°08'W; 45°54'N	20.8	$5.38 \times 10^{-2}$

Sampling No.	Date	Time (EST)	Position	Temperature °C	Specific Conductance (mhos)
41	2-VIII-66	0500	42°30'W; 45°50'N	21.5	5.56 x 10 <sup>-2</sup>
42	"	0900	40°52'W; 45°46'N	20.8	5.63 x 10 <sup>-2</sup>
43	"	1300	39°11'W; 45°41'N	20.8	5.61 x 10 <sup>-2</sup>
44	"	1655	37°32'W; 45°37'N	19.5	5.56 x 10 <sup>-2</sup>
45	"	2000	36°17'W; 45°32'N	20.0	5.55 x 10 <sup>-2</sup>
46	2-VIII-66	2400	34°40'W; 45°27'N	21.2	5.65 x 10 <sup>-2</sup>
47	3-VIII-66	0400	33°02'W; 45°22'N	20.2	5.69 x 10 <sup>-2</sup>
48	"	0800	31°21'W; 45°17'N	20.5	5.67 x 10 <sup>-2</sup>
49	"	1200	29°45'W; 45°12'N	20.5	5.64 x 10 <sup>-2</sup>
50	"	1600	28°04'W; 45°07'N	20.3	5.66 x 10 <sup>-2</sup>
51	3-VIII-66	1900	26°45'W; 45°02'N	20.1	5.68 x 10 <sup>-2</sup>
52	"	2300	25°08'W; 44°58'N	20.0	5.60 x 10 <sup>-2</sup>
53	4-VIII-66	0300	23°30'W; 44°53'N	20.2	5.67 x 10 <sup>-2</sup>
54	"	0700	21°50'W; 44°48'N	20.7	5.64 x 10 <sup>-2</sup>
55	"	1100	20°11'W; 44°43'N	20.6	5.66 x 10 <sup>-2</sup>
56	4-VIII-66	1500	18°33'W; 44°38'N	19.9	5.71 x 10 <sup>-2</sup>
57	"	1800	17°21'W; 44°33'N	19.9	5.72 x 10 <sup>-2</sup>
58	"	2200	15°43'W; 44°29'N	19.3	5.71 x 10 <sup>-2</sup>
59	5-VIII-66	0205	14°01'W; 44°24'N	19.4	5.72 x 10 <sup>-2</sup>
60	"	0600	12°27'W; 44°20'N	20.0	5.64 x 10 <sup>-2</sup>
61	5-VIII-66	1000	10°51'W; 44°17'N	20.3	5.64 x 10 <sup>-2</sup>
62	"	1400	09°17'W; 44°11'N	19.9	5.68 x 10 <sup>-2</sup>
63	"	1800	07°38'W; 44°07'N	19.1	5.68 x 10 <sup>-2</sup>
64	"	2200	05°59'W; 44°01'N	20.0	5.62 x 10 <sup>-2</sup>
65	6-VIII-66	0200	04°19'W; 43°56'N	20.4	5.60 x 10 <sup>-2</sup>
66	6-VIII-66	0610	03°12'W; 43°36'N	21.0	5.51 x 10 <sup>-2</sup>

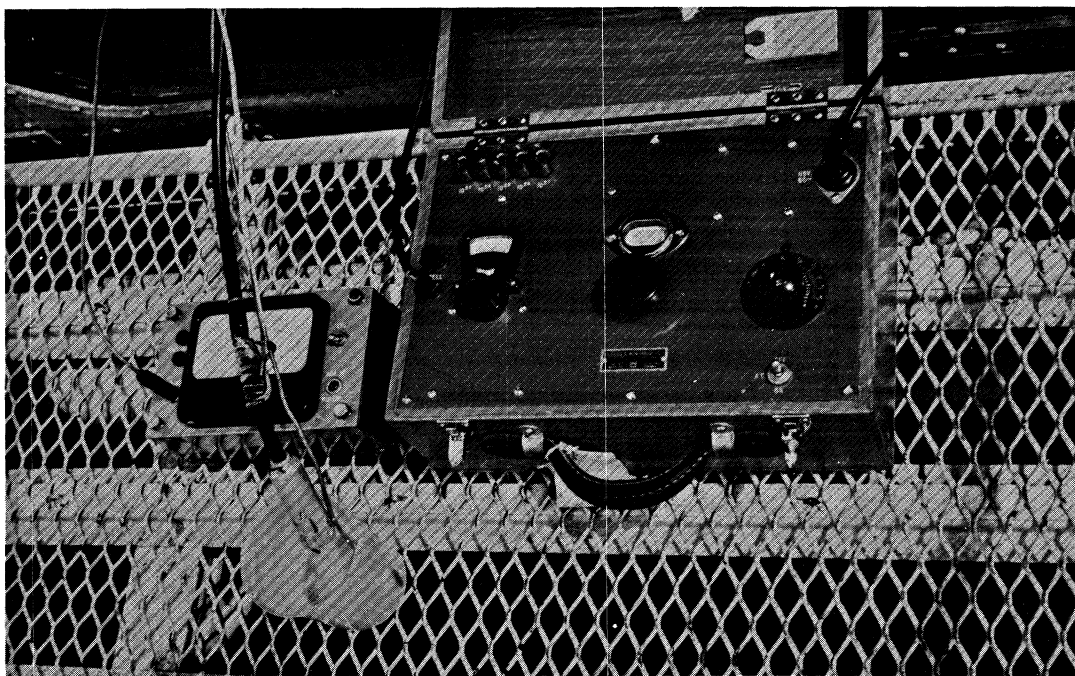


Figure 7. Setup for measuring conductivity.

for fresh water they can be converted to values equivalent to salinity by a conversion factor reported by McLain (1963). Simultaneous measurements of salinity were occasionally made with a Nurnberg "Marine Hydrometer" as a check on the measurements made with the conductivity bridge. This could not be done in fresh water where the concentrations of dissolved salts were far below the range measured by the hydrometer or in the open Atlantic where the roll of the ship precluded the use of the hydrometer.

#### Sampling Particulate Organic Matter

Three aliquots of water were filtered separately through membrane filters each time a water sample was obtained (Figs. 8-9). The filters were then dried in a desiccator over silica gel and were brought back to the Ann Arbor laboratory where the amount of particulate organic matter on each filter was determined by the method described by Robertson and Powers (1965).

#### Sampling Dissolved Organic Matter

The water from which the particulate matter had been removed was placed in polyethylene bottles and frozen. The bottles were kept in a



Figure 8. Measuring out water sample aliquot for filtration.

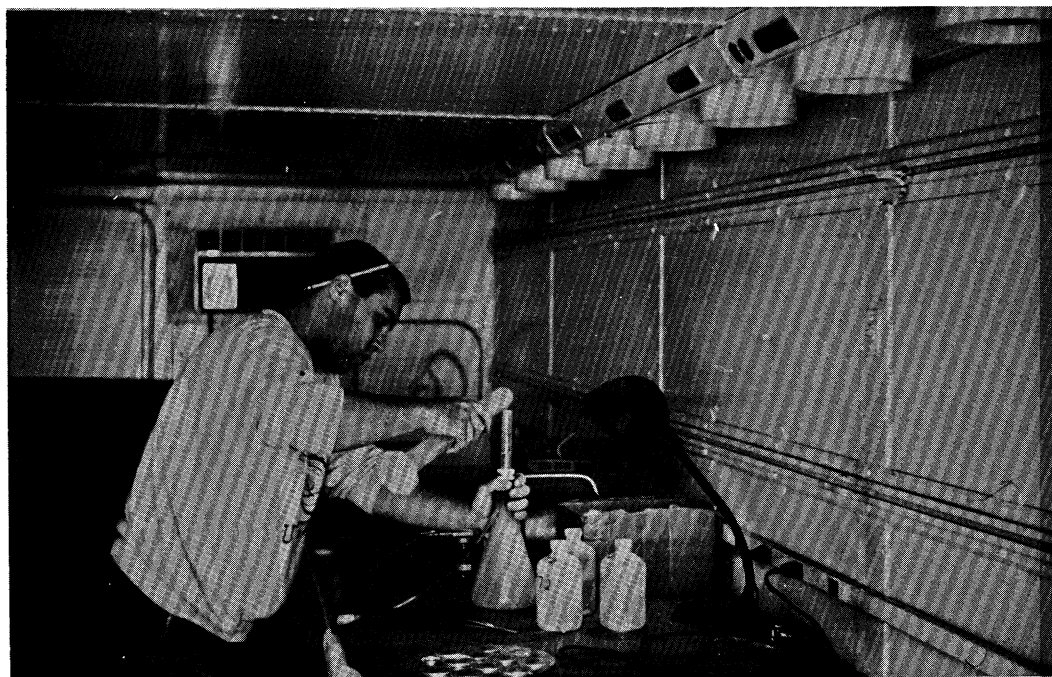


Figure 9. Filtering aliquot for determination of particulate and dissolved organic matter.

freezer in the mobile lab until arrival in Spain and then were transferred to the ship's food freezer so the electricity lines could be disconnected from the lab. When the ship returned to Detroit, the frozen samples were taken to Ann Arbor where they are being analyzed for their content of dissolved organic matter and organic carbon. The method used for analyzing organic matter is a loss on ignition technique similar to that employed for measuring particulate organic matter, while the analysis of organic carbon uses a titrametric method with potassium dichromate as the oxidizing agent.

#### Sampling the Zooplankton

Samples of zooplankton were obtained through the use of the Continuous Plankton Recorder (Fig. 10), an instrument which collects a continuous sample of plankton while being towed behind a vessel at the ship's normal speed. Collections were obtained from the fresh water at the mouth of the St. Lawrence River into the salt water of the estuary and across the Gulf of St. Lawrence almost to Newfoundland, as well as from Lakes Erie and Ontario. The instrument was lost south of Newfoundland when the outboard



Figure 10. Continuous Plankton Recorder on deck next to winch.

eye of the towing cable parted; thus, we were unable to sample in the open Atlantic. The areas sampled are shown in Figure 6.

The collections are being analyzed to determine what organisms are present and the quantities of each in the different areas sampled. The analysis of the freshwater samples is being carried out in our laboratory in Ann Arbor while that of the saltwater samples is being done by the Scottish Marine Biological Association Oceanographic Laboratory in Edinburgh, Scotland, as part of their routine survey of the North Atlantic plankton. The Edinburgh laboratory also has July Recorder samples from part of the area crossed after we lost our Recorder and has promised us access to the results of the analysis of these samples.

## CONCLUSIONS

As the collections have not been completely analyzed, it is too early to draw any final conclusions concerning the success of the project. However, the sampling program went smoothly, and there seems every reason to believe that the data collected will provide the basis for a very interesting comparison of the biological properties of the environments visited. A preliminary look at the temperature and conductivity measurements shows that several different environments can be distinguished in both fresh and salt water on the basis of these measurements.

One fact especially seems to be pointed up by Project Neptune Limnos. The use of a Research Ship of Opportunity for one cruise entailed more preparation and brought up more problems than would normally be encountered if the same research were to be done on a research vessel. This was largely due to the general lack of experience with the use of commercial ships for research. An agency to coordinate RSO programs and to furnish advice would greatly improve the situation and also the scientist's efficiency. Even with such an agency, the author feels that many single cruise projects could best be done from the regular research ships. This most certainly does not apply, however, to programs which need several cruises or more than one ship such as projects that entail samples repeated in time. Here the RSO concept will be most useful. These types of projects are very expensive for research ships and so have been largely neglected in oceanographic research. For example, we are still badly in need of such basic information as monthly charts of average surface temperature and salinity for great parts of the oceans. The use of commercial vessels could provide an inexpensive method of gathering such survey data and so greatly supplement the programs carried out by research vessels.

It should not be concluded, however, that RSO programs will only be useful for large-scale surveys of such standard parameters as temperature and salinity. Many characteristics of the aquatic environments need to be surveyed and could be with our present methodology. From the biological aspect such things as the abundance of zooplankton and the concentration of chlorophyll and particulate organic matter immediately come to mind. Further, some non-survey work could most easily be done using the RSO con-

cept; for example, the acquisition of a time series of samples from the same location and yet far from shore. Due to the expense, this has been largely impractical through the use of research vessels.

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